ELECTRICAL POWER QUALITY ANALYSIS IN DEPARTMENT EDUCATION MECHANICAL ENGINEERING , FT UNY

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***Abstract*—The purpose of this research is to determine the electrical load profile and power quality of the power distribution system in the Department of Mechanical Engineering Education, Faculty of Engineering, Yogyakarta State University. The power quality study will provide recommendations for improving one of the electrical parameters, namely the power factor, and compare the measured electrical quantities with existing standards. This electrical power quality analysis was carried out starting with measurements on the electrical panels in the Department of Mechanical Engineering Education, the panels include Fabrication SDP, CNC and lathe machine SDP, welding machine SDP, lighting load and AC load using a power quality analyzer (A3Q) measuring instrument. The measurement data includes apparent power, active power, reactive power, current, voltage, frequency, Current THD, voltage THD, and power factor. The measurement data is then processed into data in the form of a comma-separated values file (csv) which will then be converted into excel data (xls). This conversion data will then be analyzed and then compared with the existing power quality standards. Based on the results of the measurements and analysis carried out, it shows that the overall power factor value on the SDP panel and all loads in the machine direction is still below 0.86 and there is a neutral current caused by an unbalanced load. The largest neutral current value is on the CNC panel, which is 21.46 amperes.**

Keywords— power quality, power factor, electrical panel, Department of Mechanical Engineering Education, power quality standards

I. INTRODUCTION

Reliability of the electric power system and the quality of electrical energy play a crucial role in supporting people's lives. This is due to the dependence of various sectors, such as industry, telecommunications, mining, and public transportation, on the availability of electricity for optimal operation. Companies operating in these sectors have the potential to experience significant losses if disruptions occur, such as sudden power outages or unstable voltage quality. These conditions can lead to operational interruptions or decreased product quality, potentially leading to damage or defects[1][2].

Based on data from the Directorate General of New, Renewable Energy and Energy Conservation under the Ministry of Energy and Mineral Resources, energy demand increased by 6.29%, with total consumption reaching 1,220 million barrels of oil equivalent (BOE). In line with energy supply trends, the consumption level in 2023 was recorded as the highest within the past six years.

In 2023, the industrial sector will be the primary contributor to energy demand, accounting for 45.60%. Next comes transportation at 36.74%, followed by households at 12.35%, trade and services at 4.44%, and other sectors at 0.87%. This high industrial dominance is influenced by the large amount of energy consumed, particularly by coal and natural gas, in various industrial activities. [3][4][5].

Indonesia's energy consumption in the commercial sector is 4.44%, one of which is used to support facilities and infrastructure at universities in Indonesia..[6] Indonesian universities with engineering faculties are among the relatively high electricity users. This is due to learning activities dominated by practical work and the use of various equipment and supporting materials that are entirely dependent on electricity. [7]. Yogyakarta State University is one of the universities that has a Faculty of Engineering, energy consumption at Yogyakarta State University is quite high in the Faculty of Engineering, especially in the Department of Mechanical Engineering Education due to the use of practical tools in the form of machines. The Department of Mechanical Engineering Education has various types of machines such as fabrication machines, automatic machine tools (CNC), manufacturing aids (CAM), gas welding (MIG, TIG, Asitelin), SMAW welding and hydraulic pneumatics. The use of these electrical loads increasingly affects the quality of electrical power, so the demand for developing something to maintain a stable system and power quality is very necessary.

Based on this, in this research, the author wants to know the characteristics of the load and power quality of the electrical power distribution system in the Department of Mechanical Engineering Education, Faculty of Engineering, Yogyakarta State University.

II. MATERIALS AND METHODS

A. Tool Needs Analysis

The research was conducted using two types of measuring instruments: the Analyst 3Q, a 3-phase power quality meter, and an infrared thermometer. The Analyst 3Q is a measuring device used to analyze the quality of electrical power in a power system. The equipment used in this measurement is from the LEM brand. [8] [9]. This tool can measure electrical quantities simultaneously and in real time. The ANALYST 3Q is equipped with 4 CTs and 4 voltage clamps, as shown in fig 1:

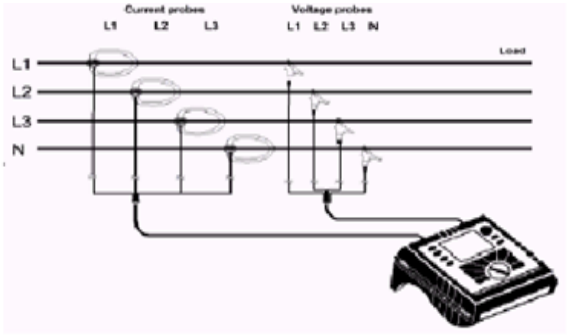


Fig 1. How to measure using Analyst 3Q[9].

An infrared thermometer is a temperature measuring instrument that works optically by detecting infrared radiation emitted by an object and then converting it into a temperature value. This tool is very useful for measurements in conditions where the use of thermocouples or other sensors is not possible or does not provide accurate results. In this study, the device used was a Hioki brand infrared thermometer[10][11].



Fig 2. How to measure using infrared thermometer

Laptop is also required to analyze the measurement results. The software used to assist in power quality analysis is WinA3Q version 2.12 and TOP 200. WinA3Q displays measurement parameters, and TOP 200 is a software tool for reading data from various measurement instruments.

B. Data Collection Method

The data collection process will be carried out at the Main Distribution Panel (MDP) at the Faculty of Engineering's central office, then at the Sub Distribution Panel (SDP) of the Mechanical Engineering Education Department. Measurements at the SDP will take approximately 7 hours to determine the load profile in the Mechanical Engineering Education Department. Data collection at the Mechanical Engineering Education Department follows the following flow.

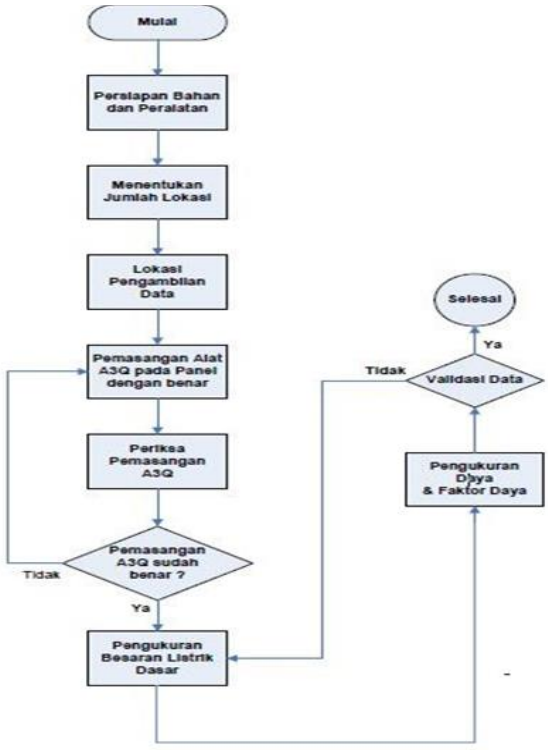


Fig 3. Flowchart of data retrieval flow

C. Analysis Method

The analysis method applied utilizes TOP 200 devices and A3Q software. The recorded data in (.a3q) format is then converted into PQIDF format for further processing purposes. The PQIDF data is then converted into a comma separated values file (CSV). Further analysis, the data obtained from the PQ measurement form, obtained data include: Apparent power, Real power, Reactive power, Current, voltage, frequency, Total Harmonic Distortion (THD) Current, Total Harmonic Distortion (THD) Voltage, Voltage Unbalance. The power quality measurement mode does not display the power factor (PF), for the power factor in Power Quality (PQ) mode is searched based on existing data, namely the division between real power and apparent power.

III. Results And Discussion

A. Data Collection Location

This research was conducted on sub-distribution panels (SDP) in the Department of Mechanical Engineering Education, Faculty of Engineering, Yogyakarta State University. The single-line electrical diagram of the Department of Mechanical Engineering Education can be seen in the fig 4.

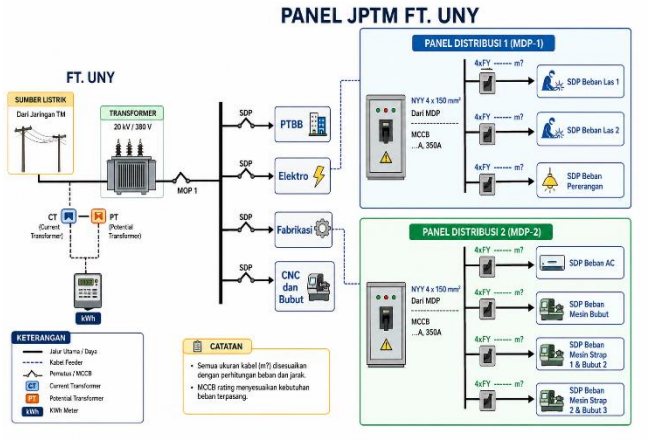


Fig 4. Single line electrical diagram of UNY Mechanical Engineering Department

B. *Measurement results*

Based on the measurement data that has been obtained, the next step is to carry out a power quality analysis on the fabricated Sub Distribution Panel (SDP), CNC machined Sub Distribution Panel (SDP)..

1. SDP Fabrication

a. Voltage

Based on the measurement results at the Fabrication SDP, the average voltage (Volts) on the R phase, S phase, T phase and maximum voltage, minimum voltage on each phase can be seen in the table. I.

TABLE I. VOLTAGE MEASUREMENT RESULTS

Parameter	Voltage Per Phase		
	R	S	T
Average	223,73 V	225,31 V	223,89 V
Max	228,32 V	229,71 V	228,19 V
Min	220,47 V	222,18 V	220,34 V

The permissible value based on the Indonesian national standard PUIL 2000 is a normal voltage range of -5% to +5% of the nominal voltage. [12]. An electrical system with a voltage of 220 V will be considered normal if :

220 V – (220 V x 10 %) ≤ standard voltage ≤ 220 V + (220 V x 5 %)

= 198 V ≤ 220 V≤ 231 V

Based on the calculations above, the voltages in the R, S, and T phases of the fabricated SDP are considered normal.

The allowable voltage unbalance value according to the National Electrical Manufacturers Association (NEMA) Standard is no more than 5%.[13]. The voltage imbalance in the fabricated SDP is 0.33%, so the voltage balance is still normal. Serious problems will occur in motors and electrical equipment with three-phase induction systems due to the voltage unbalance.

How to overcome abnormal voltage by installing a voltage regulator and overcome voltage unbalance by dividing the load usage equally on each phase..

b. Electric current

Based on the measurement results at the Fabrication SDP, the average current (Amperes) in the R phase, S phase, T phase and the maximum current, minimum current in each phase can be seen in Table 2.

TABLE II. CURRENT MEASUREMENT RESULTS

Parameter	Per-Phase Current			
	R	S	T	N
Average	4.98 A	13.35 A	6.08 A	0.98A
Max	39.45A	53.07A	40.94A	1.49A
Min	0.22A	5.96A	0.68A	0.71A

The current measurements on the R, S, and T phases in the fabricated SDP show an unbalanced current, with leakage current to the neutral. The impact of an unbalanced current is that the motor load will heat up quickly. To overcome this unbalanced current, the load distribution must be balanced.

c. Total Harmonic Voltage Distortion

According to the IEEE 519-2014 standard, harmonic distortion must be minimized to maintain power quality and stability. Based on the measurement results on the Fabrication Machine SDP, the average Total Harmonic Voltage Distortion (THD V) on the R phase, S phase, T phase and the maximum voltage THD, minimum voltage THD on each phase can be seen in table 3.

TABLE III. PRESENTASE THD VOLTAGE

Parameter	THD Measurement of Per-Phase Voltage (%)		
	R	S	T
Average	2.30	1.84	2.13
Max	2.50	2.05	2.35
Min	1.99	1.56	1.83

According to IEEE 519-2014 standard, harmonic distortion must be minimized to maintain power quality and stability.[14]. The permissible THD percentage value of voltage based on IEEE Standard 519 and 1159 is not more than 5% for a 69 KV network. The THD value of voltage on the CNC Machine SDP does not exceed the standard of 5%. The impact of harmonic voltage can interfere with the control used in electronic systems, heating in machines and transformers but if THD> 5%,

harmonic distortion can be reduced by installing an active filter installed on the panel.

d. Total Harmonic Current Distortion

Based on the measurement results on the Fabrication SDP, it is known that the average Total Harmonic Current Distortion (THD I) on the R phase, S phase, T phase and the maximum current THD, minimum current THD on each phase can be seen in table 4.

TABLE IV. PRESENTASE THD CURRENT

Parameter	Per-Phase Current THD Measurement (%)		
	R	S	T
Average	19,07	13,64	18,85
Max	71,81	34,90	59,83
Min	7,27	8,08	7,09

The permissible current THD percentage value based on IEEE Standard 519 and 1159 is not more than 15% for a current range of 100-1000 amperes and a network voltage of 69 KV. In the R phase and S phase, THD I exceeds the specified standard. The impact of current harmonics is that the rms value of both voltage and current is greater, heating in cables and in electrical machines, but if THD> 5%, harmonic distortion can be reduced by installing an active filter installed on the panel.

e. Power Factor

Based on the measurement results at the Fabrication SDP, the average power factor in the R phase, S phase, T phase and the maximum power factor, minimum power factor in each phase can be seen in table 5.

TABLE V. POWER FACTOR MEASUREMENT RESULTS

Parameter	Per-Phase Power Factor Measurement		
	R	S	T
Average	0.32	0.45	0.29
Max	0.55	0.59	0.81
Min	0	0.3	0

PLN specifies that the power factor should not be lower than 0.86. However, based on the calculation results, the average power factor at the fabricated SDP is 0.35, which is significantly below the required standard. This low power factor is primarily attributed to the operation of electrical equipment with dominant inductive characteristics. A reduced power factor leads to an increase in reactive power consumption, which may result in kVARh penalty charges imposed by PLN. Furthermore, the rise in recorded electrical energy consumption (kWh) contributes to higher operational costs due to increased overall electricity usage [15].

Power factor improvement can be achieved by installing capacitor banks in distribution panels. Prior to installation, analysis and calculations are required to determine the appropriate capacitor capacity to achieve optimal reactive power compensation based on load conditions.

2. CNC Machine SDP

a. Voltage

Based on the measurement results on the CNC Machine SDP, the average voltage on the R phase, S phase, T phase and maximum voltage, minimum voltage on each phase can be seen in table 6.

TABLE VI. VOLTAGE MEASUREMENT RESULTS

Parameter	Per-Phase Voltage		
	R	S	T
Average	225,16 V	228,54 V	226,87 V
Max	230,34 V	233,75 V	232,04 V
Min	209,61 V	213,10 V	210,76 V

The permissible value based on the Indonesian national standard PUIL 2000 is a normal voltage range of -5% to +5% of the nominal voltage. An electrical system with a voltage of 220 V will be considered normal if:

220 V – (220 V x 10 %) ≤ standard voltage ≤ 220 V + (220 V x 5 %)

= 198 V ≤ 220 V≤ 231 V

Based on the calculations above, the voltages in the R, S, and T phases of the CNC machine's SDP are considered normal.

The allowable voltage unbalance value according to NEMA standards is no more than 5%. The voltage unbalance in the fabricated SDP is 0.56%, so the voltage balance is still normal. Serious problems can occur in motors and electrical equipment with three-phase induction systems due to unbalanced voltage.

To address abnormal voltages, install a voltage regulator and address the unbalanced voltage by evenly distributing the load across each phase.

b. Electic Current

Based on the measurement results on the CNC Machine SDP, the average current (A) in the R phase, S phase, T phase and the maximum current,

minimum current in each phase can be seen in table 7.

TABLE VII. CURRENT MEASUREMENT RESULTS

Parameter	Per-Phase Current			
	R	S	T	N
Average	31,08 A	22,5 A	32,1 A	21,46 A
Max	86,32 A	88,7 A	122,3 A	55,23 A
Min	12,14 A	5,05 A	1,2 A	9,41A

The current measurement results on the R, S, T phases in the SDP of the CNC Machine are unbalanced and there is a leakage current to the neutral of 21.46 Amperes. The impact of an unbalanced current is that the motor load will heat up quickly, to overcome the unbalanced current, the load distribution must be balanced.

c. Total Harmonic Voltage Distortion

Based on the measurement results on the CNC Machine SDP, it is known that the average Total Harmonic Voltage Distortion (THD V) on the R phase, S phase, T phase and the maximum voltage THD, minimum voltage THD on each phase can be seen in table 8.

TABLE VIII. PRESENTASE THD VOLTAGE

Parameter	THD Measurement of Per-Phase Voltage (%)		
	R	S	T
Average	3,00	2,73	2,60
Max	3,75	3,59	3,79
Min	2,45	2,12	1,95

The permissible THD percentage value of voltage based on IEEE Standard 519 and 1159 is not more than 5% for a 69 KV network. The THD value of voltage on the SDP of CNC Machines does not exceed the standard of 5%. The impact of harmonic voltage can interfere with the control used in electronic systems, heating in machines and transformers, but if THD > 5%, harmonic distortion can be reduced by installing an active filter installed on the panel.

d. Total Harmonic Current Distortion

Based on the measurement results on the CNC Machine SDP, the average Total Harmonic Current Distortion (THD I) on the R phase, S phase, T phase and maximum current THD, minimum current THD on each phase can be seen in table 9.

TABLE IX. PRESENTASE THD CURRENT

Parameter	Per-Phase Current THD Measurement (%)		
	R	S	T
Average	29,93	36,81	8,70
Max	60,52	68,51	41,71
Min	3,75	4,04	2,38

The permissible current THD percentage value based on IEEE Standard 519 and 1159 is no more than 15% for a current range of 100-1000 amperes and a network voltage of 69 KV. In the R phase and S phase, THD I exceeds the specified standard. The impact of current harmonics is that the rms value of both voltage and current is greater, heating in cables and in electrical machines, but if THD > 5%, harmonic distortion can be reduced by installing an active filter installed on the panel.

e. Power Factor

Based on the measurement results on the CNC Machine SDP, the average power factor in the R phase, S phase, T phase and maximum power factor, minimum power factor in each phase can be seen in table 10.

TABLE X. *POWER FACTOR MEASUREMENT RESULTS*

Parameter	Per-Phase Power Factor Measurement		
	R	S	T
Average	0,66	0,40	0,80
Max	0,97	0,93	1
Min	0,47	0,14	0,50

PLN stipulates that the power factor must not be less than 0.86. Based on calculations, the average power factor in the CNC Machine Power Plant (SDP) is 0.62. This power factor is lower than the value set by PLN. The low power factor in the fabricated SDP is caused by the use of electrical equipment with highly inductive characteristics. This decrease in power factor implies increased reactive power consumption, potentially incurring kVARh fines from PLN. Furthermore, the increase in measured electrical energy (kWh) also impacts operational costs due to higher electricity consumption.

Power factor improvement can be achieved by installing capacitor banks in distribution panels. Prior to installation, analysis and calculations are necessary to determine the appropriate capacitor capacity so that reactive power compensation can be optimally achieved according to load conditions.

IV. Conclusion

The load profile in the Department of Mechanical Engineering Education, Faculty of Engineering, University of Yogyakarta (FT UNY) on the Fabrication panel sub-distribution is as follows: Average voltage is 224.31 Volts, Total current in phase R, S, T is 24.41 Amperes, Total active power in phase R, S, T is 2248.61 Watts, Total reactive power in phase R, S, T is 4774.03 VAR, Total apparent power in phase R, S, T is 5480.73 VA, Average frequency is 49.95 Hz, Total harmonic voltage distortion has an average percentage of 2.09%, Total harmonic current distortion has an average percentage of 17%, Average power factor of phase R, S, T is 0.35.

The load profile in the Department of Mechanical Engineering Education, Faculty of Engineering, Yogyakarta State University (FT UNY) on the CNC Machine sub-distribution panel is as follows: Average voltage is 226.71 Volts, Total current in the R, S, and T phases is 85.81 Amperes, Total active power in the R, S, and T phases is 14,234.7 Watts, Total reactive power in the R, S, and T phases is 11,514.7 VAR, Total apparent power in the R, S, and T phases is 18,926.54 VA, Average frequency is 49.91 Hz, Total harmonic voltage distortion has an average percentage of 2.77%, Total harmonic current distortion has an average percentage of 25%, Average power factor of the R, S, and T phases is 0.62. The analysis results on the sub-distribution panel show the following electrical quantities related to power quality: The voltage at the fabrication SDP and CNC Machine is still normal because it does not exceed the PUIL standard. 2000, the voltage imbalance in the fabrication SDP was 0.33% and in the CNC Machine SDP was 0.56%. The voltage balance was still normal because it did not exceed the NEMA standard of 5%

The results of current measurements on the fabricated SDP and CNC machines show an imbalance in load distribution and there is a current leak to the neutral, this will cause the motor to heat up quickly, to overcome the unbalanced current is the load distribution must be balanced or reinstall the load distribution. The percentage value of THD voltage on the fabricated SDP and CNC machines does not exceed the standard of 5% so that the percentage value of THD voltage is still normal. The percentage value of THD current on the fabricated SDP and CNC machines exceeds the standard of 15% specified by IEEE 519 so that there is an abnormality in the total percentage of harmonic current distortion, the impact of which is heating on the cables and on electrical machines. The way to reduce harmonic distortion is by installing an active filter. The average value of the power factor on the fabricated SDP is 0.35 and the CNC machine is 0.62. The power factor is lower than the amount set by PLN. The decrease in the power factor can result in the payment of a kVARh fine to PLN, in addition to the increase in kWh will result in the large costs that must be paid for electricity usage. However, if THD > 5%, harmonic distortion can be reduced by installing an active filter installed on the panel.

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